13.3 - 13.4 : Equilibrium & Pressure

Pressure Expressions

So far we have looked at equilibria in terms of concentration (M). Since many chemical reactions take place in the gas phase, now we look at concentration from a pressure perspective.

Consider this alteration of the Ideal Gas Law:

$$PV = nRT \quad \Rightarrow \quad P = \left(\frac{n}{V}\right)RT = CRT$$

Where C equals n/V : the number of moles per liter. C then represents the molar concentration of the gas.

Pressure Expressions (Continued)

In the ammonia forming reaction:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

the equilibrium expression can be rewritten in terms of molar concentrations:

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{C_{NH_3}{}^2}{(C_{N_2})(C_{H_2}{}^3)} = K_C$$

Equilibrium Partial Pressure

In terms of the equilibrium partial pressures of the gases:

$$K_P = \frac{P_{NH_3}{}^2}{(P_{N_2})(P_{H_2}{}^3)}$$

Both symbols K and K_P are used commonly for concentrations, but the symbol K_P is always in terms of partial pressures.

Finally, using a previous general reaction:

$$\boxed{K_P = \frac{(P_C)^l (P_D)^m}{(P_A)^j (P_B)^k}}$$

1. Partial Pressure Example

Nitrosyl chloride (NOCl) forms from the reaction of nitrogen monoxide and chlorine gas. Balance the reaction, then determine K_P given the following information:

P_{NOCl} = 1.2 atm
P_{NO} = 5.0 E -2 atm
P_{Cl2} = 3.0 E -1 atm

$$2NO_{(g)} + Cl_{2(g)} \rightleftharpoons 2NOCl_{(g)}$$

Making, and using the equilibrium expression:

$$K_P = \frac{P_{NOCl}{}^2}{(P_{NO_2})^2(P_{Cl_2})} = \frac{(1.2)^2}{(5.0E-2)^2(3.0E-1)} = \boxed{1.9E3}$$

Calculating K from K_P

If either K, or K_P is known at some temperature, this convenient process can convert one to the other.

First, one must know the change in moles (Δn) of gas from start to finish:

$$\boxed{\Delta n = n \ products \ - \ n \ reactants}$$

Then the expression becomes:

$K_P = K(RT)^{\Delta n}$	R = 0.0821L atm/K mol T = Kelvins

2. Calculating K From K_P

Using the value of K_P obtained in the previous example, calculate the value of K at 25ºC for the same reaction.

We can use the conversion from K_P to K, after determining the molar volume change:

$$\Delta n = n\ products\ -\ n\ reactants$$

$$= 2\,moles\ gas - 3\,moles\ gas = \boxed{-1\,mole\,gas}$$

Being sure to proceed in Kelvins: 298 K:

$$K_P = K(RT)^{\Delta n} = 1.9E3 \bullet (0.0821 \bullet 298)^{-1} = \boxed{78}$$

Heterogeneous Equilibria

So far we have discussed reactions occurring in the gas phase: all reactants and products are gases.
This is homogeneous equilibrium.
In heterogeneous equilibrium, more than one phase is present.
It is important to realize: **the position of heterogeneous equilibrium does not depend on the amount of pure solids or liquids present.**

The reason for this is that concentrations of solids and liquids cannot change: they will be consumed in a reaction, but their concentration remains the same.

3. Heterogeneous Eq. Example

Write the expressions for K and K_P for the reaction: Solid phosphorus pentachloride decomposes to liquid phosphorus trichloride and chlorine gas.

First: make a balanced reaction.

$$PCl_{5(s)} \rightleftharpoons PCl_{3(l)} + Cl_{2(g)}$$

It would seem that the equilibrium expression should simply be expressed as:

$$K = \frac{[PCl_3][Cl_2]}{[PCl_5]}$$

However, since the only component where concentration is variable is chlorine, K is actually:

$$K = [Cl_2]$$

and K_P is:

$$K_P = P_{Cl_2}$$

Homework

Preview 12.5 - 12.6

12.3 - 12.4 Problems in your Booklet
Due: Next Class